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ABSTRACT

This study examined changes in 19 teachers' beliefs across the first 2 years of a professional development program in cognitively guided instruction (CGI). The study involved five teams of mathematics teachers and teacher educators. Teams attended professional development workshops on several occasions. Each team met monthly to discuss their progress. The teachers received a visit each month during mathematics instruction from one of the teacher educators and once each semester from a researcher and an experienced CGI teacher. Data collection occurred during the first day of the three day workshops. Participants responded to three sets of open-ended questions that examined what they believed teachers needed to know to teach mathematics effectively, what they considered the important outcomes of primary mathematics instruction, and what they considered the most important aspects of teaching primary mathematics. Participants changed their beliefs in three areas (teacher's view of children, teacher and student roles, and skill acquisition and problem solving) over the 2 years, with changes varying by category and grade level. Eight teachers continued to refer to children's needs collectively. Four teachers continued to believe that their major role was to impart knowledge to children rather than provide experiences whereby children can construct their own knowledge. Two teachers believed that skill acquisition was the most essential outcome of mathematics instruction. (SM)

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Changing Teacher's Beliefs Through Professional Development

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The findings reported in this paper address changes in teachers' beliefs across a professional development program that is preparing mathematics educators to implement and disseminate Cognitively Guided Instruction (Carpenter, Fennema, Peterson, & Carey, 1988). Examined were beliefs about the knowledge needed to teach mathematics effectively in kindergarten through third grade and the most important student outcomes of that instruction. The study is part of a five-year teacher enhancement project (NSF Grant ESI-09450518).

Cognitively Guided Instruction (CGI) is an approach to teaching and learning mathematics whereby teachers use research-based knowledge about children's mathematical thinking to learn specifics about individual students for the purpose of adjusting instruction to match the learning needs of students. CGI teachers, compared with teachers who are not prepared in CGI, spend more time having their students solve problems, listen more to their students, and are more likely to expect students to find multiple solution strategies to problems than do teachers who are not prepared in CGI (Carpenter, Fennema, Peterson, Chiang, & Loef, 1989). CGI also has been shown to increase student performance on both standardized and problem-solving tests (e.g., Fennema, Carpenter, & Peterson, 1989), and to impact changes in teachers' beliefs about the role of the teacher and the student, the relationship between skills and understanding, and the sequencing of mathematics topics (Fennema, Carpenter, Franke, Levi, Jacobs, & Empson, 1996; Peterson, Fennema, Carpenter, & Loef, 1989).

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Fennema et al. (1996), in a four-year longitudinal study of 21 primary teachers, identified five levels of cognitively guided instruction and five levels of cognitively guided beliefs. Teachers at the lowest instructional level provide limited to no opportunities for children to solve problems or share their thinking, whereas teachers at the highest level of instruction include a variety of problem solving opportunities for children and provide ongoing opportunities for children to share their thinking. Teachers at the lowest level of beliefs view children as not being able to solve problems without instruction, whereas teachers at the highest level of beliefs espouse that children can solve problems across mathematics content domains, without instruction. The latter group of teachers also believe in eliciting and attending to children's thinking for the purpose of modifying instruction to meet the learning needs of individual students. Fennema et al. (1996) also found that changes in level of instruction were positively related to class achievement in concepts and problem solving. It would appear that if teachers are to develop an understanding of children's mathematical thinking and to build on this understanding in their instruction, professional development programs need to focus on helping teachers develop a perspective that includes knowing children as individuals, helping children negotiate meaning and understanding of various mathematical concepts, and providing opportunities for children to progress from problem solving to skills-based understanding rather than focusing on learning skills as prerequisites to problem solving.

Whether preparation in CGI impacts beliefs about more global aspects of mathematics education such as teacher knowledge and expected student outcomes has not been examined. This is not unexpected since evaluation procedures for professional-development programs generally tend to focus on changes that are directly related to the respective program's focus.

Yet, because of the emphasis in CGI on planning instruction based on children's thinking, it is expected that as teachers are being prepared in CGI, they will change their beliefs about what teachers need to know and what students should be able to do as recipients of this type of instruction. The present study is an initial attempt to examine this hypothesis. Specifically examined across the first two years of a five-year professional development program in CGI were changes in teachers' beliefs about (a) what teachers need to know in order to teach mathematics and (b) what are important outcomes of mathematics instruction.

Method

Procedures

The project is structured around five teams of mathematics educators from different regions of North Carolina, with each team initially consisting of six primary-grade teachers and two teacher educators who serve as team co-leaders. Because of a variety of factors, including the use of local funds to increase the size of one team, the teams ranged in size from 5 to 9 people at the end of the second year.

During the first two years of the project, professional development workshops were held in May 1995 (3 days), June 1995 (10 days), July 1996 (8 days), and June 1997 (7 days). During Summer 1996, the teams also met at their respective site for 2 days in August to plan for the 1996-97 school year. In addition, each team met after school approximately once a month to discuss the members' progress. Finally, each teacher was visited approximately once a month during mathematics instruction by one of the team's co-leaders, and once each semester by one of the two principal investigators of the project and one of six experienced CGI teachers who are project staff members.

Subjects

Although 30 female teachers are participating in the project, 19 served as subjects in the present study because complete data were available for them across the first two years of the project. At the beginning of the study, the subjects consisted of 3 kindergarten, 5 first-grade, 4 second-grade, 5 third-grade, 1 fourth-grade, and 1 fifth-grade teacher(s). Also, their years of teaching experience from 2 to 25.

Instrumentation

The findings reported in this paper are based on data collected during the first day of the May 1995, June 1996, and July 1997 workshops. Each subject provided a written response to three sets of open-ended questions: (a) What do you believe K-3 teachers need to know in order to teach mathematics effectively? Why are those things important? (b) What do you believe are the most important outcomes of mathematics instruction in the primary grades? Why? and (c) What do you believe are the most important aspects of teaching mathematics in the primary grades? Why?

Data Analysis

Data for the third- through fifth-grade teachers were combined, and a content analysis on the subjects' verbatim written responses was then completed by the three authors. First, responses were dissected, fragments were grouped by content, and category labels were identified for clusters of comments. Second, evidence for each category was discussed until agreement was reached on the nature of evidence that would be accepted for categorizing responses according to these frameworks. Third, data were coded independently and compared. When necessary, dissimilar codings were negotiated until agreement was achieved.

Results and Conclusion

Based on the data analysis, subjects' beliefs about what teachers need to know to teach mathematics effectively in the primary grades and the most important student outcomes of that instruction were divided into three categories: teacher's view of children, role of teacher and students, and skill acquisition and problem solving. In general, the subjects changed their beliefs in these three areas across the two years, but the changes varied by category and grade level as illustrated in Table 1. Subjects' responses are summarized below by category, with representative belief statements included.

Teacher's View of Children

At the beginning of this study, all the subjects indicated that it was important to know about general stages of cognitive development by age or grade level, and they referred to expected student outcomes based on those developmental levels. As illustrated in Table 1, 13 of the subjects referred to children collectively when citing the importance of knowing about a student's cognitive development. They made no reference to knowing about the learning of individual children. At the end of two years in the professional development program, eight of these subjects continued to refer to children collectively.

- I believe K-3 teachers need to know the research and theories on how children think. The developmental approach and how it effects children differently. Once a teacher has an understanding of these areas in young children, they will be able to facilitate the children learning more effectively.

Five teachers, however, made a major shift in their beliefs to include a focus on knowing children as individual learners. After two years, their beliefs were similar to the perspective of teachers 2,

3, 14, and 18 at the beginning of the study, i.e., teachers need to know about students as individuals in order to teach effectively.

- [It is important to find] ways to meet individual needs [and to know] that all children do not learn the same way.

As illustrated in Table 1, this initial perspective appeared to be tenuous for Teachers 3, 14, and 18, since their beliefs shifted away from a focus on individual students during the second administration. At the conclusion of two years in the professional development program, they again cited the importance of focusing on individual students.

- Through the exploration and discourse which will occur, children will begin to construct their own knowledge. What better way to meet the needs of different students than by helping each one build their own understanding.

Teacher 2 continued to focus on the importance of knowing children as individuals at the end of the first year, but she made no reference to children in her responses at the end of the second year of the program. Teachers 17 and 19 also ended the second year of the program believing that effective teaching includes knowing students as individuals, but they differed from the other subjects because they began the study with beliefs that fluctuated between knowing children as individuals or collectively.

Role of Teacher and Student

At the beginning of the study, 14 subjects referred to the role of participants in mathematics instruction as being an important component of effective classroom instruction, with each respondent referring to the teacher as the distributor of knowledge. Respondents appeared to share a non-constructivist perspective about teacher and student roles during mathematics

instruction (i.e., a teacher's role is to tell and/or show students what they need to know and/or do).

- Teachers need to know strategies for problem solving. By using many strategies, the teacher makes it easier for a child to see ways of solving problems.
- Teachers need to know how to ask questions in order to make a child think more critically.

After two years of participation in the professional development program, 1 of the 14 teachers made no reference to the role of classroom participants, while four maintained a non-constructivist orientation.

- The teacher can ... demonstrate the many ways to solve problems using manipulatives.

Seven teachers shared beliefs that were beginning to shift slightly toward the constructivist perspective of focusing on the importance of children's thinking as it affects mathematical learning and knowing how to help children negotiate meaning from their learning experiences. Their beliefs supported a minor change toward children constructing their own knowledge.

- It's okay for a child to use manipulatives to solve a problem.
- In order to teach mathematics effectively, teachers should know what the students are thinking.

Seven subjects supported a constructivist approach to teaching and learning mathematics. They indicated that it was essential for teachers to plan instruction so that children are able to understand and interpret their and other children's solution strategies.

- Teachers in the primary grades need to allow children to explore math concepts in many different situations. Children also need to be given the opportunity to talk and write about

their discoveries. Through the exploration and discourse which will occur, children will begin to construct their own knowledge.

- It is important to provide these problems and allow students to develop their own understanding instead of forcing an understanding on them.

Skills Acquisition and Problem Solving

At the beginning of the study, all the subjects provided responses that indicated beliefs pertaining to the role of problem solving and skills acquisition during mathematics instruction. Twelve teachers shared a belief that learning basic skills is essential for teaching mathematics effectively. Their beliefs support a non-constructivist perspective.

- The most important outcomes are that students achieve to the expected level and master the competencies required for their grade level.

By the conclusion of the second year of the project, two teachers (#8 and 12) expressed a belief that supported skills acquisition as the most important outcome of instruction. Teachers 3, 4, and 10, however, were beginning to shift toward a problem-solving focus.

- [The most important outcomes are] to produce confident and competent students in mathematics.
- [The most important outcome is] students with a good understanding of numbers. Students who can manipulate numbers with ease!
- [The most important aspect of teaching is] children developing number sense so that numbers are not abstractions floating around in the dark abyss of the universe.

The eight remaining teachers made major shifts in their beliefs that resulted in the perspective that problem solving is the means through which skills can be attained.

- I believe the most important aspect of teaching mathematics in the primary grades is providing opportunities for the children to explore numbers and mathematics concepts.... Instead of merely memorizing facts, they have a tool box of strategies to use in problem solving.
- The most important aspects ... are the different approaches that can be used in solving problems and the importance of having a student explain their solution.
- The teacher can not effectively teach children until they know and understand the abilities and level of thinking mathematically to solve problems.

Four teachers (#5; 11, 16, and 18) began the professional development program with a belief that effective teaching includes a problem-solving approach to teaching and learning mathematics. Their perspective did not change across the first two years of the program. They believe that effective teaching requires a constructivist approach to teaching and learning.

- I hope to give my students power over numbers. I want them to realize they are in control of numbers and the ability to solve problems. Students need to be aware of many different methods of problem solving and how to use the different methods.
- I believe the most important aspect of teaching mathematics in the primary grades is making sure the student understands the concepts that lead to the answer. If the student knows <u>how</u> to solve and <u>why</u> the problem is solved in that way, then the children can solve any mathematics problem.

Discussion and Conclusions

As a result of the first two years of the professional development project, the subjects in general changed their beliefs about the important knowledge that a teacher needs in order to

provide effective mathematics instruction, and the important student outcomes of that instruction. However, as illustrated in Table 1, those belief changes varied by category and grade level.

During the first administration of the three sets of questions, only approximately 21% of the subjects cited the importance of teachers knowing about individual student performance in order to teach mathematics effectively. While this number increased to 53% by the end of two years, 42% of the subjects continued to view children as a collective group.

Also during the first administration, approximately 73% of the subjects shared the non-constructivist perspective that it is the teacher's responsibility to impart knowledge. By the conclusion of the first two years of the project, however, 37% of the subjects had shifted their beliefs to a constructive perspective (i.e., it is important for children to construct knowledge), while 37% of the subjects were beginning to support the idea of children being actively engaged in constructing knowledge. Twenty-one percent, however, maintained the belief that children learn best when they are told by the teacher what they need to know and do.

All subjects made some reference to the role of problem solving and skills acquisition at the beginning of the study, with only 21% sharing a belief that a problem-solving approach is essential for teaching mathematics effectively. By the end of the first two years of professional development, however, approximately 74% of the subjects believed that mathematics should be taught through a problem-solving approach, and approximately 16% were beginning to change their perspective about problem solving and skills acquisition. Only two teachers (11%) continued to believe that skills acquisition was essential for problem solving.

In summary, the greatest change in beliefs occurred within the category of whether mathematics should be taught through a skills-acquisition or problem-solving approach. For a

majority of the subjects, the professional development program appeared to influence a shift toward a problem-solving approach to teaching and learning mathematics. This change in beliefs was expected, given the major emphasis in CGI on problem solving. In contrast, the lack of change in the subjects' view of children was unexpected since a basic principle of CGI is the need to plan instruction that meets the needs of individual students.

Based on the data analysis, differences existed in the belief changes for the subjects in this study, but there was no clear pattern of change across teachers or grades. Selected quotes of two teachers, however, illustrate the progressive shift of several subjects from a non-constructivist to a constructivist perspective, as a result of the first two years of the project.

Teacher A

- If [children] lack the basic skills, they will have difficulty functioning on a day to day basis. (Spring 1995)
- K-3 teachers need to know the mathematical ability or level their students are on so they can adapt their teaching to meet the individual's needs. (Spring 1996)
- If we understand what our children are thinking, then we can plan what problem type we will give them next to challenge their thinking. (Spring 1997)

Teacher B

- [Teachers need to know] the correct sequence of skills for each grade level. (Spring 1995)
- [It is important to find] out what the children already know before telling them what you think they need to know. (Spring 1995)
- [It is important to] listen to a child explain how he solved a problem. (Spring 1997)

Teacher B's Spring 1995 quote illustrates the transition that often occurred for teachers as they moved from a perspective of teacher as teller to teacher as listener. It appears that the teachers in this study faced the dilemma of wanting to be in control while at the same time recognizing the need to provide opportunities for students to explore their own learning. This dilemma may have been an influencing factor on the extent to which subjects changed or did not change their beliefs.

Some patterns did emerge across the first two years of the professional development program concerning teachers with a non-constructivist perspective at the beginning of the study. One teacher (i.e., #12) held a non-constructivist perspective in all three belief categories after two years. The professional development program appeared to have had little or no effect on her beliefs. Teacher number 11 also did not change her perspective across the first two years of the program, but she began the study with a non-constructivist perspective in her view of children and the role of the teacher and students, and a constructivist approach to problem solving and skills development. Three other teachers (#4, 8, and 10) changed their beliefs minimally as a result of the professional development program; their beliefs shifted in a more constructivist orientation in only one category. The beliefs of teachers 4 and 10 appeared to shift slightly toward the importance of a problem-solving approach to teaching and learning rather than a skill-acquisition focus, while the beliefs of teacher 8 appeared to shift slightly away from the perspective of the teacher as distributor of knowledge. It also is interesting that all the teachers who had a rating of 1 in one or more categories were first- or second-grade teachers. While an explanation for this finding is not clear, there may be an effect due to differences in instructional emphases at each grade level. The focus on introducing and developing an understanding of basic operations in the traditional first- and second-grade curriculum may have had an impact on the

views of the first- and second-grade teachers about children in general, the importance of skills acquisition, and the role of the teacher and students. Relatedly, the non-independence of kindergarten children may have had an impact on the beliefs of the teachers at that level. The heavy focus in kindergarten on developing communication skills, solving problems in general, and focusing on each child's level of "readiness to learn" may have influenced the teachers' perspectives across the three categories. Finally, the more constructivist views of the third- and fourth-grade teachers might be related to the different foci in the intermediate-grades curriculum to include increased application of factual knowledge in problem-solving activities, children working collaboratively on given tasks, and the development of written and verbal communication skills.

Summary

Despite the overall changes in subjects' beliefs across the two years, eight teachers did not move away from a belief that focused on the importance of basing instruction based on children's needs collectively, four teachers continued to believe that their major role was to impart knowledge to the children rather than provide experiences whereby children are able to construct their own knowledge, and two teachers believed that the acquisition of skills was the most essential outcome of mathematics instruction. These results are rather surprising given the extent and duration of the professional development program involved, the ongoing support provided teachers throughout each year, and the basic principles of CGI (i.e., mathematics should be learned through a problem-solving approach and instructional planning should be based on children's thinking). Although an explanation of the lack of change for these teachers is not clear, there may have been an effect due to change of grade level taught. Six teachers (#7, 8, 9, 12, 16,

and 18) changed grade levels during the second year of the study which may have affected their beliefs. For the subjects in this study, years of teaching experience did not appear to be an influential factor. For example, included among the subjects with 20 or more years of teaching experience were #7 (major shift in two areas of beliefs), #12 (maintained a non-constructivist perspective), and #18 (maintained a constructivist perspective). Further, included among the subjects with five or less years of teaching experience were #4 (little or no shift in her non-constructivist perspective), #13 (major shift in two categories of beliefs and continuation of a non-constructivist perspective in the third area), and #19 (concluded study with constructivist perspective in all three categories).

Research shows that changing instruction is difficult and takes considerable time and support. In particular, Fennema et al. (1996) found that implementing CGI over four years did not result in dramatic change for all teachers. Three of the 21 teachers (14%) in that study showed no change in level of beliefs about the role of the learner and the teacher, the relationship between skills and understanding, and the sequencing of mathematics topics, while 6 teachers (28%) showed a change of only one level in the level of beliefs. The present study examined whether teachers' beliefs changed across the first two years of a CGI professional development program, relative to what primary teachers need to know to teach mathematics effectively and what teachers believe to be important student outcomes of that instruction. Based on the findings, participation in the professional development program in this study had little or no impact (i.e., response codings of 1 in Table 1) on changing the non-constructivist beliefs of 42% of the subjects relative to planning instruction based on individual children's needs, 27% of the subjects concerning the role of the teacher and students, and 26% of the subjects relative to problem solving and skills acquisition.

Whether these beliefs will change during the remaining years of the project remains in question. Teacher knowledge and student outcomes were not a direct component of the professional development program in this study, but the findings of this study support reconsideration of this orientation since implementation of CGI is directly related to planning and providing instruction that has a problem-solving focus and is based on children's thinking. As documented by the results of this study, professional development programs need to include components that are aligned with the expected outcomes of the inservice-education program.

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Table 1

Codings of Teachers' Beliefs by Grade Level and Administration

	Response Codings								
	View of Children			Role of Teacher and Students			Skill acquisition and problem solving		
Subjects	1995	1996	1997	1995	1996	1997	1995	1996	1997
Kindergarten									
1	1	2	3	1	2	2	2	2	3
2	3	3	0	0	2	3	1	3	3
3	3	1	3	1	0	2	1	2	2
First Grade									
4	1	1	1	1	1	1	1	1	2
5	1	3	1	1	3	3	3	3	3
6	1	3	3	1	0	0	1	2	3
7	1	1	3	1	2	2	1	2	3
8	1	1	1	1	1	2	1	1	1
9	1	1	1	1	1	2	1	2	3
Second Grade									
10	1	1	1	1	1	1	1	2	2
11	1	1	1	1	0	1	3	3	3
12	1	1	1	1	2	1	2	1	1
13	1	2	1	1	2	3	1	3	3
Third-Fifth Grade									
14	3	2	3	1	2	3	1	2	3
15	1	3	3	0	0	2	1	2	3
16	1	1	3	0	3	3	3	3	3
17	2	3	3	0	1	2	2	3	3
18	3	2	3	0	3	3	3	3	3
19	2	1	3	1	3	3	1	2	3

0 — No reference to category
1 — Non-constructivist perspective for respective category:
View of Children: instructional planning is based on children as a group
Role of Teacher/Students: teachers need to tell or show children how to solve problems
Skills/Problem Solving: skills development is a prerequisite for successful problem solving
2 — Unclear beliefs about category; fluctuating between non-constructivist and constructivist perspective
3 — Constructivist perspective for respective category
View of Children: instructional planning is based on the needs of individual children
Role of Teacher/Students: children need to construct knowledge
Skills/Problem Solving: mathematics should be taught through a problem-solving approach